All cont'd.

7.(amended) The plane optical circuit according to claim 6 wherein the width of the core is tapered along an optical axis in the part proximate to the side surface.

8. The plane optical circuit according to claim 6 wherein a refractive index difference between the core and the clad is larger than that of the optical fiber.

REMARKS

The above-referenced application has been amended to correct minor grammatical errors. The Applicants submit that no new matter has been added. The Applicants request that this Amendment be entered and be considered as part of the examination.

Attached hereto is a marked-up version of the changes made to the specification and claims by the current amendment. The attached page is captioned "**Version with markings to show changes made**."

Respectfully submitted,

CHRISTIE, PARKER & HALE, LLP

By Richard J. Paciulan

Richard J. Paciulan
Reg. No. 28,248
626/795-9900

RJP/cah

Application No. 10/067,552

VERSION WITH MARKINGS TO SHOW CHANGES MADE

(Brackets with strikethroughs indicated deletions. Underlinings indicate insertions)

In the Specification

The paragraph on Page 1, lines 11 - 16, is amended as follows:

Recently, [~~such a~~] wavelength division multiplexing (WDM) optical transmission systems [~~system~~] have [~~has~~] rapidly developed that are [~~is~~] capable of increasing [~~a~~] transmission capacity [~~as much as the number of wavelengths~~] by transmitting a plurality of optical signals each having a different wavelength in a single optical fiber simultaneously.

The paragaph on Page 2, lines 1 - 8, is amended as follows:

Those optical devices are mainly realized using silica optical waveguides. In an optical transmission system of an intermediate or longer haul, a single mode silica optical fiber which is capable of transmitting optical signals at low loss is used as a transmission line. It is for this [~~the~~] reason that both the [~~of a~~] silica optical waveguide and the [~~a~~] silica optical fiber are made of the same quartz materials and therefore can be optically coupled at low loss by direct connection.

The paragraph from Page 3, line 17, to Page 4, line 10, is amended as follows:

As stated above, a MFD of a silica optical waveguide with a larger relative refractive index difference (is as small as 5 μm and accordingly the coupling loss with a silica optical fiber becomes larger. To solve the above reciprocal relation between the curve loss and the coupling loss, a [~~such~~] method has been proposed that reduces the refractive index of a core of a silica waveguide in the coupling part with an optical fiber and at the same time enlarges a core diameter. This method is called [~~as~~] a thermally expanded core (TEC) method. In essence [~~To put it concretely~~], after connecting a silica optical waveguide and a silica optical fiber, a core of the silica optical waveguide near to the connecting part is locally heated with an ultraviolet laser or the like to diffuse the elements doped to the core of the silica optical waveguide. Accordingly, in the area near to the connecting part of the silica optical

waveguide, the refractive index of the core reduces and the core diameter enlarges causing the increase of the MFD and the decrease of the coupling loss.

The paragraph from Page 4, line 23, to Page 5, line 8, is amended as follows:

In a conventional system to extend a core width, it is possible to perform a batch forming through patterning of the core. However, the silica optical waveguide becomes a multi mode waveguide in the connecting part, namely the part in which the core diameter is extended and therefore it is unavoidable that a high-order lateral mode generates. The optical signals converted to the high-order mode either cannot or <u>minimally</u> [~~hardly~~] couple with the single mode silica optical fiber and accordingly the coupling efficiency of those optical signals decreases.

The paragraph on Page 5, lines 11 - 13, is amended as follows:

It is therefore an object of the present invention to provide an optical connecting structure capable of forming a plurality of connecting parts in <u>one operation</u> [~~a lump~~] and realizing a high coupling efficiency.

The paragraph on Page 6, lines 12 - 20, is amended as follows:

The above configurations make it possible to optically couple the plane optical waveguide and the optical fiber at a high efficiency. It is sufficient as far as at least one of the width and depth of the core is tapered as it approaches to the optical fiber, and therefore it is relatively easy to form the structure. It is especially easy to taper the width of the core as it approaches to the optical fiber. In addition, this structure reduces costs because even if a large number of optical coupling parts are required, it is possible to perform all the tapering in <u>one operation</u> [~~a lump~~].

The paragraph on Page 7, lines 2 - 8, is amended as follows:

Even if the relative refractive index difference (between the core and clad is larger than that of the optical fiber, the taper configuration functions to approximate both propagation constants so that the optical coupling is performed easier. Consequently, it enables <u>the</u> [~~to~~]

use of plane optical waveguides having a high Δ and the ability to make the optical devices utilizing such waveguides more compact.

The paragraph on Page 7, lines 15 - 16, is amended as follows:

FIG. 1 shows a perspective view of the main elements of an embodiment according to the invention;

The paragraph on Page 9, lines 5 - 14, is amended as follows:

The core 12 of the silica waveguide 10 and the core 22 of the silica optical fiber 20 meet at the side of the silica optical waveguide 10. In this embodiment, the width of the core 12 of the silica optical waveguide 10 tapers in the longitudinal direction at a part 16 of approximately 1000 μm connecting to the optical fiber 20 as shown in FIG. 2(B). The tapered part 16 keeps a constant core depth [~~width in~~] thickness as shown in FIG. 2(A). The tip width of the core 12 is 0.5 μm for example. Such a tapered form of the core 12 can be easily obtained using a photolithograph method when the core 12 is formed on a quartz substrate.

The paragraph from Page 11, line 4, to Page 12, line 3, is amended as follows:

In the core 12 which width and depth are constant, light propagates in a single mode with a mode field diameter of approximately 5 μm. In the tapered part 16, since the width of the core 12 gradually narrows, the light also gradually converts to a radiation mode. Because the length of the taper part 16 is sufficient long as 1000 μm, the conversion from the fundamental guided mode to the radiation mode is adiabatically performed, and the loss due to the mode conversion becomes extremely low. The radiation mode is not shut in the core 12 and accordingly its MFD gradually increases. As shown in FIG. 3, although field patterns of the propagation light indicate slight differences between the width and thickness directions, both keep the forms that roughly approximate a Gaussian distribution. At the tip of the tapered part 16, the average value of the MFD in the width and thickness directions becomes approximately 9.0 μm, which is close to the MFD (approximately 9.5 μm) of the optical fiber 20. The shape of the tapered part 16 is symmetrical relative to an optical axis. Therefore, the propagating direction of the radiation mode equals [~~to~~] that of the guided mode, and the propagating direction of the light does not change even after almost all the light is [~~lights~~]

shifted to the radiation mode. Such are [~~The above-described things are considered as~~] the reasons why the coupling loss decreases when the tip width of the core 12 is extremely narrowed as shown in FIG. 4.

In the Abstract of the Disclosure

The Abstract of the Disclosure is amended as follows:

A method and apparatus [~~An object of this invention is~~] to improve coupling efficiency of a silica optical waveguide having a high relative refractive index difference and a single mode optical fiber. A silica optical waveguide [~~(10)~~] consists of a single mode optical waveguide, and its core [~~(12)~~] is originally a rectangle. A width of the core [~~(12)~~] of the silica optical waveguide [~~(10)~~] is tapered at a predetermined length part [~~(16)~~] connecting to an optical fiber [~~(20)~~]. A depth thickness of the core [~~(12)~~] in the tapered part remains [~~(16) is~~] constant.

In the Claims

1.(amended) An optical coupling structure to connect an optical fiber and a plane optical waveguide, comprising:

a core having same cross-sectional dimensions as [~~a~~] core cross sectional dimensions of the plane optical waveguide at one side connecting to the plane optical waveguide, and having width and depth smaller than a core diameter of the optical fiber at a fiber interface [~~the other~~] side connecting to the optical fiber wherein at least one of width and depth of the core is tapered along an optical axis proximate to the fiber interface side [~~as near to the other side~~]; and,

clad to surround the core.

2.(amended) The optical coupling structure according to claim 1 wherein the width of the core is tapered along the optical axis proximate to the fiber interface side [~~as near to the other side~~].

3.(amended) The optical coupling structure according to claim 1 wherein [~~a~~] the plane optical waveguide [~~comprising the core and clad~~] is a single mode optical waveguide and the optical fiber is [~~comprises~~] a single mode optical fiber.

6.(amended) A plane optical circuit to optically connect to optical fiber at a side surface of the plane optical circuit, comprising:

a core having a first refractive index, at least one of width and depth of the core being tapered along optical axis in a part proximate [~~near~~] to the side surface, the width and the depth of the core at the side surface being smaller than a core diameter of the optical fiber; and,

clad having second refractive index smaller than the first refractive index to surround the core.

7.(amended) The plane optical circuit according to claim 6 wherein the width of the core is tapered along an optical axis in the part proximate [~~near~~] to the side surface.

Application No. 10/067,552

COPY OF PAPERS
ORIGINALLY FILED

OIPE JC144
MAR 19 2002
PATENT & TRADEMARK OFFICE

In the Abstract of the Disclosure

A12

A method and apparatus to improve coupling efficiency of a silica optical waveguide having a high relative refractive index difference and a single mode optical fiber. A silica optical waveguide consists of a single mode optical waveguide, and its core is originally a rectangle. A width of the core of the silica optical waveguide is tapered at a predetermined length part connecting to an optical fiber. A depth thickness of the core in the tapered part remains constant.